It can scarcely be necessary to add that transient phenomena of other kinds, such as bands of auroral light at periods when auroras are frequent and intense, sometimes appear in the zodiac, and are mistaken for zodiacal light by inexperienced observers.

## THE DIRECTION OF LOCAL WINDS AS AFFECTED BY CONTIGUOUS AREAS OF LAND AND WATER.

By T. H. DAVIS. Dated West Haven, Conn., July 21, 1906.

Thru my previous researches on local surface wind direction I have been led to believe that, so far as stations near large water areas are concerned, a large percentage of observed directions is due to the direct influence of contiguous land and water. For this reason I have continued my research in this line, selecting such stations as seem to be open to direct sea or lake winds. My computations have been somewhat voluminous, but I have endeavored to condense them so that the results can be studied without extensive explanatory matter.

For each station I have taken those winds which blow from the cardinal points, the paths of which have free ingress to the land, and the principle upon which I have based the study of the data is that of land and sea breezes. These appear to me to be much more extensive and to exert greater influence on local directions than is generally supposed or admitted. I strongly believe that winds of this character should receive greater consideration than hitherto, as valuable factors in the determination of local weather.

I have found, during the comparatively short time in which I have obtained continuous tracings of directions from a vane well exposed near the coast, what I believe to be indisputable proof of wind direction altogether independent of that which precedes, accompanies, or follows the passage of great areas of high or low pressure to the north or to the south of this point. It may be argued that all local winds are entirely the result of highs and lows, and that such as I have observed are simply averages of the effects of these areas. On the other hand I am led strongly to believe that a large percentage of winds over stations near large water areas is mainly, if not entirely, due to land and water contiguity. Careful study of weather maps will show how very frequently, over the Great Lakes and along the coasts, the winds of highs and lows are deflected.

The records of winds by only eight cardinal points do not constitute entirely satisfactory data for research. I believe that the scale of sixteen points should be used; this I did in former years when observing for the British Meteorological Office and am doing now at my own station. The results given in this paper are, however, from eight point observations, as recorded in the MONTHLY WEATHER REVIEW for the several years under consideration. Some of these in the earlier years seem to be not quite so correct as could be wished, particularly as to the large number of calms recorded for some of the stations. In my computations I have eliminated all these calms by adding them, proportionately, to those winds showing the greatest frequency.

In order that the results obtained should be as comprehensive as possible the following exposed stations were selected as representating the Pacific and Atlantic coasts, the Gulf of Mexico, and the Great Lakes:

| | |
|---|---|
| San Francisco, Cal<br>San Diego, Cal | Pacific coast. |
| Galveston, Tex | Gulf of Mexico. |
| Savannah, Ga<br>New York, N. Y<br>New Haven, Conn<br>Boston, Mass<br>Eastport, Me | Atlantic coast. |
| Marquette, Mich<br>Chicago, Ill<br>Cleveland, Ohio<br>Toronto, Ont | Great Lakes. |

I should much have liked to include several other stations, but not possessing the necessary information was unable to do so.

The results subsequently shown were obtained by tabulating from the records in the monthly reports as published by the Weather Bureau, the actual number of hours the wind blew from those points over the water areas, from which it had an unobstructed path to the land. This was done for each point, each month for twelve successive years, 1891–1902. The total of each column was divided by twelve to obtain an average number of hours for each point in each month and from this their percentages were determined to the first decimal point.

For example:

*San Francisco, January, hours.*

| Year. | W. | SW. | W.+SW. |
|---|---|---|---|
| 1891 | 94 | 78 | 172 |
| 1892 | 133 | 75 | 208 |
| 1893 | 117 | 43 | 160 |
| 1894 | 79 | 184 | 263 |
| 1895 | 32 | 129 | 161 |
| 1896 | 56 | 99 | 155 |
| 1897 | 46 | 12 | 58 |
| 1898 | 77 | 33 | 110 |
| 1899 | 97 | 59 | 156 |
| 1900 | 44 | 24 | 68 |
| 1901 | 126 | 33 | 159 |
| 1902 | 97 | 19 | 116 |
| Total | 998 | 788 | 1,786 |
| Average | 83 | 66 | 149 |
| Percentage | 11.2 | 8.9 | 20.1 |

This table will serve as a general explanation of the method adopted for computation of results for each station selected.

In this paper I have restricted my observations to the winds flowing from seaward points to the land, as these seem to be more marked than those from land to sea, by reason, no doubt, of the more marked effect of the intensity of insolation. The monthly and annual variation of this intensity very probably accounts for the variability in the frequency of true sea winds in the earlier and later months of the several years under consideration, for while the accompanying tables of average percentage indicate considerable regularity in the change of prevalence of the sea winds from January to July and August, and from these months to December, yet each individual month during the 12-year period, in most cases, shows considerable variation in frequency. But the total number of sea winds for each year of the same period does not show any very great variation, at any rate not more than what may be expected from the effect of average insolation for each year.

In two or three cases I endeavored to make comparison between the frequency of sea wind and the mean annual temperatures during the whole period, but was unable to discover any reliable relation. This really may be expected, because, after all, the conditions of insolation are such that it does not necessarily follow that intermittent hot periods should produce those atmospheric effects which are induced by superheated land areas.

The determination of sea and land winds is complex because of the difficulty of quantitatively separating actual sea winds from the total winds composed of these and of those which are the effects of high and low areas. This I believe to be too abstruse at present for any attempt at separation to be made, but I do believe that the result of my research indicates pretty clearly that the percentages do actually prove a large frequency of true sea winds blowing independently of any other atmospheric condition, because of the regular progression of the figures from winter to summer and the same regular recession from summer to winter. If it were possible to eliminate the influences of high and low areas I firmly believe that percentages would be found showing pretty perfect progression and recession without any pronounced variability.

In referring particularly to the actual numerical results obtained I may remark that, in order to obtain the sea directions, lines were in each case laid off on a reliable map showing the true paths of winds from the sea, and then a careful study was made of the recorded hourly frequency. The latter enabled me to select those winds which I believed were absolutely influenced by the effect of the contiguity of land and water and the directions so determined are given in Table 1.

TABLE 1—*Directions of effective sea winds referred to in text.*

| | |
|---|---|
| San Francisco, Cal. | West, southwest. |
| San Diego, Cal. | West, southwest, northwest. |
| Galveston, Tex. | East, southeast, south, southwest. |
| Savannah, Ga. | Southeast, south. |
| New York, N. Y. | Southeast, south. |
| New Haven, Conn. | Southeast, south, southwest. |
| Boston, Mass. | Northeast, east. |
| Eastport, Me | South, southwest. |
| Marquette, Mich. | North, northeast, east. |
| Chicago, Ill. | Northeast, east, southeast. |
| Cleveland, Ohio | Northeast, north, northwest. |
| Toronto, Ont. | East, southeast, south, southwest. |

TABLE 2.—*Average monthly percentages of sea winds for twelve years, 1891–1902.*

| Month. | San Francisco. | San Diego. | Galveston. | Savannah. | New York. | New Haven. | Boston. | Eastport. | Marquette. | Chicago. | Cleveland. | Toronto. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 20.1 | 45.2 | 51.9 | 11.7 | 12.2 | 21.9 | 8.4 | 15.0 | 11.0 | 19.5 | 23.3 | 38.0 |
| February | 41.3 | 55.2 | 55.0 | 17.3 | 10.5 | 19.9 | 14.2 | 16.8 | 21.2 | 24.3 | 30.3 | 33.6 |
| March | 58.1 | 63.1 | 67.5 | 28.5 | 17.3 | 28.4 | 19.4 | 25.1 | 32.0 | 36.7 | 37.8 | 33.9 |
| April | 71.9 | 74.0 | 77.0 | 35.0 | 23.5 | 37.3 | 28.0 | 27.9 | 38.3 | 46.4 | 41.6 | 40.0 |
| May | 81.2 | 79.0 | 81.7 | 40.2 | 28.5 | 49.0 | 29.3 | 44.5 | 35.0 | 44.5 | 42.9 | 43.9 |
| June | 89.0 | 90.4 | 85.7 | 42.5 | 30.0 | 50.0 | 26.9 | 47.5 | 33.5 | 47.3 | 39.8 | 46.0 |
| July | 91.2 | 85.9 | 86.4 | 33.2 | 32.3 | 50.7 | 21.1 | 57.1 | 31.9 | 46.0 | 38.3 | 48.7 |
| August | 90.7 | 86.5 | 79.2 | 34.1 | 30.7 | 43.2 | 22.7 | 47.3 | 34.5 | 50.1 | 41.9 | 44.5 |
| September | 82.8 | 79.1 | 65.5 | 26.9 | 28.0 | 37.0 | 20.4 | 42.6 | 20.1 | 34.8 | 34.2 | 43.0 |
| October | 66.4 | 63.2 | 60.0 | 14.8 | 18.0 | 28.7 | 19.1 | 32.2 | 21.8 | 29.3 | 27.6 | 42.6 |
| November | 38.5 | 48.5 | 58.1 | 16.1 | 15.6 | 23.0 | 11.9 | 24.6 | 15.1 | 24.6 | 22.4 | 41.0 |
| December | 18.3 | 36.7 | 51.5 | 15.9 | 12.6 | 27.8 | 7.4 | 20.6 | 11.1 | 20.6 | 19.6 | 47.1 |

Each column of figures gives the average percentage of winds from sea to land for each month, based on data for the 12-year period, 1891–1902. While the figures in Table 2 show results pertaining to sea winds, it must not be supposed that they represent those winds for each month of each year. Individual months show, in the records, considerable irregularity and variation in cardinal point direction, especially in the early and later months of the year.

A very good example of such variation occurs in the case of San Diego, Cal., where the records show a considerably larger proportion of west winds in the first half of the 12-year period than in the second half, and a closely corresponding larger proportion of north winds in the second half than in the first. I find there is a sort of reciprocity among the winds blowing in from the sea, for, as the percentage frequency decreases from one point it generally increases in one of the others in fairly relative proportion. A similar variation in frequency is apparent in the San Francisco, Cal., records, and I particularly noted in those for 1893–4 a great recession of west winds and increase of southwest; also, that during the whole of the 12-year period there were considerable oscillations between west and southwest. In all the Januarys and Decembers there are marked variations in the totals of west and southwest winds, while in all the other months their total frequencies are much more equal.

Referring again to the total frequencies of sea winds for each year, for San Francisco, my computations prove a remarkable regularity, for, with the exception of 1893, the sea winds comprised from 61 to 65 per cent of the total winds blowing over this station, thus showing an average annual variation of only 4 per cent for the whole period. In 1893 the percentage of sea winds showed only 56 per cent, and this probably may be accounted for by errors of observation or some numerical error. I am not inclined to look upon it as by any means normal.

The frequencies of sea winds for San Diego do not show such marked regularity as those of San Francisco, for their annual variation was from 61 to 76 per cent, the former representing 1891 and the latter 1902. This, however, may be considered as not an excessive variation. I mention these two stations, in particular, in support of the fact that the largest proportion of winds blowing from the sea is due to causes entirely independent of general high and low pressure; that such winds are material factors in determining the climate of coastal positions; and that, by reason of the results obtained numerically from actual observations of definite conditions, they prove the value of the method, which I can not help believing to be far more practical and useful than the mathematical and dynamic theories with their voluminous calculations intended to foretell and explain such atmospheric phenomena. Every natural law, when discovered, is found to be entirely simple, and to my mind it seems that close and faithful observation of the actual workings of nature should produce more true scientific results than those sought for by the aid of trigonometric functions, the calculus and such like. These are, no doubt, valuable in the analysis of a law, its conditions and effects, after its discovery.

Taking Galveston, Tex., as a representative station for the Gulf of Mexico, we find the winds blowing from the Gulf over this place very well defined and in quite large proportion; also, that there is very little variation of the totals of these winds during each corresponding month in the whole twelve years. The entire variation of totals for each year is from 66 per cent in 1901, to 71 per cent in 1904, a range of only 5 per cent during the whole period. Galveston being a station where winds with easterly components would be expected to predominate, as a result of trade-wind effect, might not be considered an altogether satisfactory place for the determination of those winds flowing in from the Gulf as a result of land and water contiguity; but it seems to me that the percentage of Gulf winds maintains great regularity of increase and decrease at those seasons of the year when they would be actual results of such contiguity. Moreover, an analysis of true Gulf wind direction shows for the average year 10 per cent of direct east winds, 28 per cent southeast, 20 per cent south, and 10 per cent southwest. The last two directions can hardly be considered as having direct connection with trade-wind effect. Furthermore, the maximum frequency of direct east wind occurs during September, October, and November; of the southeast, from March to October; of the south, from April to August, and of the southwest during June, July, and August. I believe we can draw the same deductions from the Galveston record of wind frequency, with relation to Gulf winds, as were drawn in the cases of San Francisco and San Diego.

Turning now to the Atlantic coast, Savannah, Ga., was the most southern station selected. At this place, which shows only 26 per cent sea winds for the average year, there was a considerable variation of total annual sea winds during the 12-year period. The lowest percentage was 17 in 1902, and the highest 34 in 1894, giving an average of 17 per cent.

Savannah is somewhat unsatisfactory as a representative station, because there are some *topographical* features that might interfere with some of the sea winds, but this was the only southern coast station for which I possessed unbroken hourly records. From an analysis of the winds from each point it would appear that there is a gradual mean increase of southeast and south wind frequency from a minimum in January to a maximum in June, and thence a gradual recession from July to December, with a slight fluctuation in August and again in November. It was also found that the south winds predominate on the average in each month except September and

October, in which months southeast winds predominate, and November, when south and southeast winds are practically equal in frequency. The actual southeast and south sea winds for each month during the 12-year period are very variable, except in the months of May, June, and July, in which they show comparatively more regularity.

New York, N. Y., receives sea winds from south and southeast, which, however, must be somewhat interfered with by reason of the irregularity of the coast. Southwest winds are frequent during some of the summer months, blowing in from the direction of upper New York Bay. They are, however, so irregular and intermittent that I have not looked upon them as really sea winds. New York is not a station where we may look for very definite evidence of the effect of land and water contiguity, still it is so to some extent. At this station the total sea winds for the average year constitute 22 per cent, the variation being from 18 per cent in 1896 to 28 per cent in 1891, giving a range of 10 per cent.

New Haven, Conn., I believe to be a very fairly representative east coast station, for it is well open to the extensive waters of Long Island Sound from east-southeast, thru south to west. The water area is uninterrupted for a space of about sixteen miles. Winds direct from the Atlantic Ocean are more or less interfered with by the land effect of Long Island, which, however, is only very moderately elevated above the water surface; but, the width of this land in the path of those winds direct from the Atlantic to New Haven, being 14 to 18 miles, must have a deterrent effect on winds passing over it from the ocean direct. This is evidenced by the frequent appearance of more or less cumulus clouds directly over the Long Island land area, and it seems to me that we, in New Haven, are practically dependent upon the water area of Long Island Sound for our sea wind.

The average year shows a frequency of 6 per cent southeast, 11 per cent south, and 18 per cent southwest winds, the total sea winds from these directions being 35 per cent. This percentage shows very small variation, the lowest value for the period being 32 per cent in 1899 and the highest 39 per cent in 1891, the range being only 7 per cent during the whole twelve years. The average of 35 per cent was exceeded slightly in 1891, 1895, 1896, 1901, and 1902, and not attained in 1892, 1893, 1894, 1897, 1898, 1899, and 1900. Taking advantage of the local Weather Bureau records I made what I believe to be a very careful comparison between the range of air temperature and the frequency of sea winds; but, again, I could find no reliable relation between general temperature means and percentage of these winds. This, in all probability, is because the air temperatures were taken at an elevation of about 118 feet above the ground, and were, therefore, those of the air resulting from land and water interchange. More careful study and closer thermometrical observations near the surface of the land area at a few selected points, together with synoptic temperature records of contiguous water might show clearer connections between sea winds and selected temperatures. This I hope to work out in a subsequent paper at a later date.

I have so far been unable to find any records of the temperatures of the Long Island Sound waters near the surface. I have obtained records of deep water temperatures which Messrs. Landcraft Bros. kindly furnished, showing for the month of July in 1903, 1904, and 1905, 60° to 70°. These were taken at depths of five to six fathoms below the surface, and it is extremely doubtful if such temperatures would correspond with that of the water surface, which I think is the only datum that would be of any service in determining the relation between the temperature of the water, that of the air in contact with it, and that in contact with the adjacent land area. Probably some such system may be arranged so that results can be obtained which would clearly define the information sought.

Taking the sea winds flowing into Boston, Mass., I found, for this place, conflicting conditions and considerable monthly variation and irregularity during the twelve years. The individual months show that from May to September, both inclusive, the greater percentage of sea winds is from due east and in all the other months (except April, in which east and northeast are comparatively equal), from the northeast. It seems to me that many of the true sea winds for Boston are obscured by those arising from other causes, and they seem to suffer deflection by reason of the complex coast line and probably by the influence of the large outer bay. I quite expected to find southeast winds showing themselves as seasonal sea winds as related to this bay, but on computing these I found the percentage for the average year to be practically equal in each month, the variation being between 3.3 per cent in February, and 6.7 per cent in August, the remaining months showing a percentage between 4 and 5. For these reasons I did not include southeast winds in my computations. The total sea winds for Boston, so far as I can ascertain from the records, amount to only 19 per cent in the average year, and they varied during the twelve years from 16 per cent in 1892 to 23 per cent in 1898, the range being 7 per cent. Of the above total sea winds, 9 per cent were from the northeast and 10 per cent from the east, the former varying from 4 per cent in January and December to 14 per cent in April and May, and the latter from 7 per cent in December to 27 per cent in May.

The geographical position of Eastport, Me., renders this place liable to variability and fluctuation of sea-wind frequency. The coast line is much broken and the outlying insular land areas probably have their influence in modifying direction. In my computations for Eastport I found that the south and southwest winds were those exhibiting the seasonal progression and recession in frequency, and that these were practically the sea winds for this place. Observing that Eastport should theoretically receive northeast, east, and southeast winds resulting from sea and land effect, I computed these directions separately. The northeast sea winds appear to flow inland down the coast from the Bay of Fundy mainly during those months when it is more or less frozen over, and seem to continue doing so until the latent heat of liquefaction vanishes and the water begins to absorb heat specifically. These winds appear almost twice as frequently from January to June (both inclusive) as they do during the other months, with the exception of November, in which month they about equal the figures from January to March. The east winds seem to blow pretty exactly with the same relative frequency as the northeast winds themselves, while those from the southeast appear pretty regular in frequency (but in very small percentage) thruout the whole average year. The south and southwest winds show considerable seasonal regularity in the average year, ranging from 15 per cent in January to 57 per cent in July, thence to 21 per cent in December. The total average percentage of these sea winds is 33.4, their variation being between 27 per cent in 1901 and 39 per cent in 1895, a range of nearly 12 per cent during the whole period. If we include the winds from northeast, east, and southeast then the total percentage of sea winds for the average year reaches 54.1; but I believe the former percentage to be more correct. I believe that many of the recorded observations of winds blowing over Eastport are winds related to other causes than those producing true sea winds; yet there is, to my mind, quite enough observational evidence of the seasonal increase and decrease in frequency of winds from the water area to substantiate the existence of a fair percentage of true, independent sea winds.

The results of the computations of the frequency of winds flowing in from Lake Superior to Marquette, Mich., show some very interesting features, in which the ice-covered lake in winter, and ice-cold water of early spring seem to have direct effect in influencing definite lake winds, which seem more marked during the period of the breaking up of the ice in April and May than in any other seasonal period of the year, excepting the month of August, in which a large percentage would be expected by reason of the greater effect of solar radiation on the land area. An analysis of frequencies from the lake-wind points for the average year shows 12.6 per cent north, 9 per cent northeast, and only 3.9 per cent east. Winds directly from the east do not seem to contribute much to the total of lake winds, which for the average year is 25.5 per cent. The variation for the twelve years was between 20 per cent in 1901 and 1902 and 33 per cent in 1892, giving the rather large range of 13 per cent. The minimum percentage occurred in the last three years, 1900–1901–2.

Chicago, Ill., appears to exhibit very definite lake winds which show very fair seasonal progression and recession during each year of the whole period, with the exception of 1895 and 1896, in which years the total of lake-wind hours is much less than in the other years. The average year shows, from my computations, a total of 34.7 per cent lake winds. Here again I ventured a comparison between the winds and the mean pressures and temperatures, at Chicago, over the 12-year period, but obtained no result that would lead me to believe otherwise than that the number of hours of frequency of lake winds, as recorded in the MONTHLY WEATHER REVIEW, is not the result of general pressures and temperatures and that wind directions certainly are in very large proportion due entirely to local influence; and that, generally, they are quite separate from general circulatory effect, or that resulting from the passage of high and low areas over this point. This assertion, which applies to all such winds from water areas flowing unobstructed to the land, may seem to be a bold one, but it is the result of careful study and research into the recorded frequencies for the period under consideration. An analysis of the frequency of each wind for the average year for Chicago shows 17 per cent northeast, 7 per cent east, and 11 per cent southeast. The total lake winds for each year vary between 27.6 per cent in 1896 and 39.7 per cent in 1892. The average total for the twelve years is 34.7 per cent and the range of variation 12 per cent.

Cleveland, Ohio, is another lake station exhibiting good seasonable evidence of true lake winds. These amount to a total of 33.3 per cent for the average year, the variation being between 29 per cent in 1894 and 41 per cent in 1891, thus showing a range of 12 per cent. Of the total 33.3 per cent lake winds for the average year, 10.6 per cent were from northeast, 9.6 per cent from the north, and 13.1 per cent from the northwest.

Toronto is the only Canadian station the records of which seemed continuously reliable. My computations in this case are based on the reduction of observations to whole days, from which the percentages are calculated. I could see no other way, owing to some irregularity in the recorded hourly frequencies as published in the Canadian Monthly Weather Review.

The total lake winds for this place, for the average year, form 41.9 per cent. Of this total 13.1 per cent were east and 5.3 per cent southeast, both directions showing regular seasonal progression. The south wind, 10.9 per cent, and the southwest, 12.6 per cent, altho really lake winds do not show such seasonal regularity as do the east and southeast, and this particularly in the case of the southwest wind, the frequency of which is high in January, June, July, November, and December, while the other months are fairly equal in frequency, about 9 per cent. This would indicate winter lake effects similar to those of Marquette.

In order that this research should be as complete as possible—so far as I could judge—I calculated the resultant direction of the sea winds for each selected station, for each month of the average year. These results are given in Table 3, which shows, generally, how very closely the resultant direction persists at nearly all these places, adding, I believe, further and strong proof of the existence of a large proportion of winds due to land and water contiguity. The great importance of these, as affecting local climate surely deserves more careful consideration. Usually these winds are merely mentioned meteorologically and dismissed with comparatively short notice, conveying the idea that they are unimportant.

From a review of this paper the following may be deduced:

(1) That winds from large water areas are much more frequent on the Pacific coast and on the east coast of the Gulf of Mexico than they are on the Atlantic coast or the Great Lakes.

(2) That these winds have more persistent frequency than generally supposed.

(3) That they are important factors in determining local climate.

(4) That while they vary much in direction in individual months their annual frequency does not depart very far from the average.

(5) That while they may be, to some extent, overcome by winds from other causes, yet their existence and importance can not be doubted, and that they are true results of land and water contiguity.

Before commencing this research and during the time I have been engaged upon it, I have refrained from perusing any publication bearing upon the subject, as my desire was that it should be entirely independent and unbiased. I have relied altogether upon the information contained in those tables, published in the MONTHLY WEATHER REVIEW, which give records of the number of hours of wind frequency, and the whole of my computations are based on these.

I do not venture explanation of theory or hypothesis relative to the actual cause or causes of the winds blowing from large water areas, my endeavor being to make a statement, as clearly as possible, of actual occurrences, and I believe these to be stronger evidence of atmospheric phenomena than could be the case with theoretical or hypothetical reasoning.

NOTE.—During the short time in which I have obtained continuous tracings of wind direction, very near the coast line, I have noticed many definite changes in direction at, or near to, the times of the high and low water. I am making specific record of these and propose making the relation of change in some wind directions to tidal effect the subject of a paper at some future date.

TABLE 3.—*Resultant direction of sea winds for each month of average year, 1891–1902.*

| Month. | San Francisco. | San Diego. | Galveston. | Savannah. | New York. | New Haven. | Boston. | Eastport. | Marquette. | Chicago. | Cleveland. | Toronto. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| January | w. 20 s. | w. 19 n. | s. 21 e. | s. 16 e. | s. 14 e. | s. 28 w. | e. 24 n. | s. 36 w. | n. 23 e. | e. 3 s. | n. 17 w. | s. 9 w. |
| February | w. 18 s. | w. 13 n. | s. 34 e. | s. 18 e. | s. 20 e. | s. 24 w. | e. 27 n. | s. 32 w. | n. 31 e. | e. 3 n. | n. 12 w. | s. 2 w. |
| March | w. 17 s. | w. 8 n. | s. 28 e. | s. 16 e. | s. 23 e. | s. 13 w. | e. 21 n. | s. 31 w. | n. 29 e. | e. 9 n. | n. 4 w. | s. 30 e. |
| April | w. 20 s. | w. 8 n. | s. 31 e. | s. 15 e. | s. 25 e. | s. 4 w. | e. 23 n. | s. 26 w. | n. 29 e. | e. 14 n. | n. 1 w. | s. 38 e. |
| May | w. 21 s. | w. 3 s. | s. 24 e. | s. 16 e. | s. 24 e. | s. 7 w. | e. 20 n. | s. 20 w. | n. 27 e. | e. 17 n. | north. | s. 42 e. |
| June | w. 23 s. | w. 21 s. | s. 19 e. | s. 18 e. | s. 21 e. | s. 12 w. | e. 18 n. | s. 26 w. | n. 27 e. | e. 12 n. | n. 2 e. | s. 27 e. |
| July | w. 27 s. | w. 1 n. | s. 6 e. | s. 16 e. | s. 16 e. | s. 19 w. | e. 15 n. | s. 22 w. | n. 30 e. | e. 12 n. | n. 4 e. | s. 17 e. |
| August | w. 27 s. | w. 4 n. | s. 5 e. | s. 16 e. | s. 18 e | s. 12 w. | e. 14 n. | s. 22 w. | n. 28 e. | e. 12 n. | n. 2 e. | s. 24 e. |
| September | w. 22 s. | w. 15 n. | s. 44 e. | s. 27 e. | s. 18 e. | s. 19 w. | e. 19 n. | s. 27 w. | n. 30 e. | e. 4 n. | north. | s. 25 e. |
| October | w. 19 s. | w. 16 n. | s. 45 e. | s. 25 e. | s. 18 e. | s. 19 w. | e. 27 n. | s. 29 w. | n. 25 e. | e. 3 n. | n. 7 w. | s. 31 e. |
| November | w. 17 s. | w. 29 n. | s. 35 e. | s. 22 e. | s. 19 e. | s. 23 w. | e. 27 n. | s. 32 w. | n. 26 e. | e. 8 n. | n. 19 w. | s. 16 e. |
| December | w. 19 s. | w. 24 n. | s. 29 e. | s. 19 e. | s. 13 e. | s. 31 w. | e. 24 n. | s. 35 w. | n. 29 e. | e. 2 n. | n. 12 w. | s. 12 w. |